Macroinvertebrate Monitoring as an Indicator of Water Quality: Status Report for Niobrara River, Agate Fossil Beds National Monument, 1989-2002

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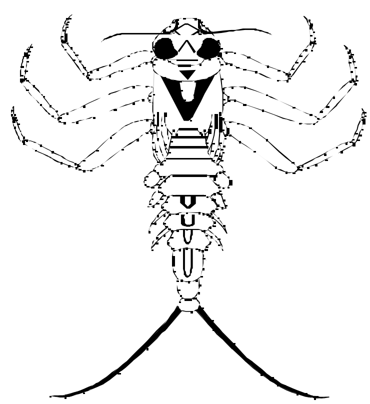

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ACKNOWLEDGEMENTS

We would like to thank all of those who have contributed to macroinvertebrate monitoring at Agate Fossil Beds National Monument, Nebraska over the years. In particular, we would like to thank Bob Manasek, Natural Resource Manager, Lil Morava, and the numerous seasonal employees who assisted with macroinvertebrate sample collection. Also, a debt of thanks is owed Lisa Thomas and Daren Carlisle, both have assisted in numerous ways to keep this monitoring focused and the results of highest quality.

INTRODUCTION

The National Park Service (NPS) began monitoring the aquatic macroinvertebrates of the Niobrara River in 1988. However, it was not until 1989 that the current sampling method was implemented (Harris et al. 1991). Sporadic sampling, mostly outside the collection season of interest (summer) for this report continued during the period 1992-1995, with funding provided by the Midwest Regional Office of NPS. Concerted monitoring efforts began again in 1996-1997, following creation of the Prairie Cluster Prototype Long-term Ecological Monitoring Program (Prairie Cluster LTEM) – a base-funded science program to monitor natural resources at Agate Fossil Beds National Monument and five other Midwestern NPS units. The purpose of this report is to summarize macroinvertebrate-monitoring data collected in 1996 through 2002, and to assess changes in community structure through time.

Benthic macroinvertebrates are the most common group of organisms used to assess water quality (Rosenberg and Resh 1993). They are attractive as indicators because they represent a diverse group of long-lived, sedentary species that react strongly and often predictably to human influences on aquatic systems (Cairns and Pratt 1993). The objectives of this biomonitoring program are to determine the annual status of stream macroinvertebrate communities in order to assess the water quality of the Niobrara River and to detect changes through time in macroinvertebrate communities.

BACKGROUND

The Niobrara River originates near Lusk, Wyoming, traverses the northern half of Nebraska from west to east and empties into the Missouri River near Niobrara. The entire river basin encompasses over 30,000 km^2 with approximately 2200 km^2 above Agate Fossil Beds National Monument. The Niobrara River meanders through the center of the park with a marshy flood plain encompassing nearly 187 ha of the park.

Natural vegetation of Agate Fossil Beds National Monument is mixed-grass prairie with the Kuchler potential natural vegetation reported as blue grama *Bouteloua gracilis*, needlegrass *Stipa comata*, and western wheatgrass *Agropyron smithii* (Stubbendieck and Willson 1986). Irrigated dry-land farming, mostly alfalfa hay is practiced in the watershed surrounding the park. However, the primary land use in the watershed is cattle grazing. The park is on the boundary of two of Omernick's (1987) ecoregion, Western High Plains and Northwestern Great Plains. The area is underlain with permeable sand and sand-rock to 150 m in depth and of Tertiary age (Harris et al. 1991). Average annual rainfall is 369 mm per year with the highest monthly precipitation occurring in May, the lowest in December (Harris et al 1991).

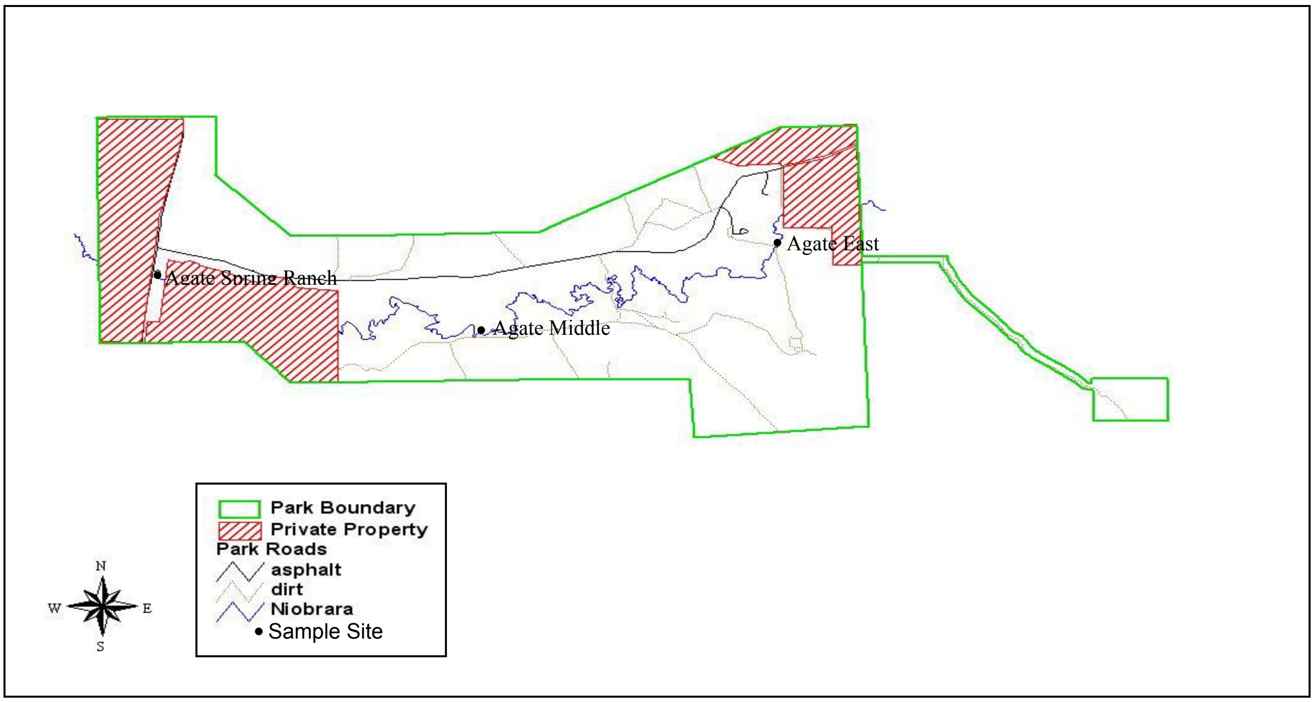
Pollution history. Water pollution from industrial or municipal effluent in the watershed above Agate Fossil Beds National Monument is largely unknown. A cattle feedlot borders the park on the west side. Water Resources Division (WRD), National Park Service conducted an extensive review of historic water quality data (1952 - 1993) for an area three miles upstream and one mile down stream of the park (Water Resources Division 1999). Water Resource Division identified one period in October 1952 when pH equaled the upper limit of EPA's chronic criteria for freshwater aquatic life. Since 1973, fecal coliform concentrations equaled or exceeded WRD bathing-water screening criterion four times. However, these four samples may have been held longer then the standard culture time before analysis. Cadmium was found to exceed EPA's acute freshwater criterion and equal their drinking water criterion in February 1992. Copper exceeded EPA's acute freshwater criterion in August 1991. Lead exceeded or equaled EPA's drinking water criterion in November 1991 and February 1992, respectively. From the results of WRD's review it is apparent that water quality of the Niobrara River within Agate Fossil Beds National Monument is high and relatively non-impaired. Monitoring efforts prior to 1952 were not identified in the WRD report (1999) or for this report.

SAMPLING METHODS

The details of field and laboratory procedures are described in Peterson et al. (1999), and summarized below.

Monitoring Sites. Harris et al. (1991) established three monitoring sites within the park, along the Niobrara River (Figure 1). However, the middle site was not monitored until 1997. Five replicate Hester-Dendy samples were collected at each site during each sampling event.

Figure 1. Macroinvertebrate monitoring sites on the Niobrara River at Agate Fossil Beds National Monument, Nebraska.



Sampling Frequency And Timing. The monitoring protocol calls for the collection of three samples, with five replicates per sample, at approximate monthly intervals during a summer sampling window defined by growing degree days (i.e. days with average daily temperature above 10°C). For Agate Fossil Beds National Monument, normal average daily temperatures fall within this range for the period 18 June through 19 September (National Weather Service). The samples included in this report were collected between 2 July and 27 September, samplers were deployed one month prior to collection dates.

Field Sampling. Benthic macroinvertebrate samples were collected from the stream with Hester-Dendy samplers following methods outlined by Peterson et al. (1999). Macroinvertebrates were carefully removed from the sampler and placed in labeled jars containing 80 % ethyl alcohol. Samples were then prepared for shipping and sent to a lab for species identification and enumeration.

Colorado State University investigators collected macroinvertebrate samples in 1989 (Harris et al. 1991). Park staff collected macroinvertebrate samples for the period 1996-2002.

Macroinvertebrates were identified and enumerated by Dr. Boris Kondratieff's lab, Colorado State University for the period 1989 (Harris et al. 1991); and by Dr. Charles Rabeni's lab, Missouri Cooperative Fish and Wildlife Research Unit, University of Missouri-Columbia for 1996-2002. Macroinvertebrates were identified to the lowest taxonomic level possible, which was generally to genus.

To insure the consistency of data collected in the future, Dr. Charles Rabeni's lab has agreed to process annually collected macroinvertebrate samples for the next five years with contract extensions possible thereafter. NPS personnel at Agate Fossil Beds National Monument will continue to collect five replicate macroinvertebrate samples from each of three sites, three times annually. Additional physical and chemical parameters will be measured each time a sample is collected.

Community Indices. The monitoring protocol recommended using a suite of four community indices to describe changes in community structure (Table 1; Peterson et al. 1999). Peterson (1996) identified four metrics to be the least redundant and most indicative of water quality from a list of nine possible metrics using Pearson correlation comparisons and a Principal Components Analysis of the correlation matrix. Additionally, we include Genus Evenness and EPT Richness in this report for the purposes of comparison with macroinvertebrate monitoring data from other sources.

Table 1. Metrics used to characterize the aquatic macroinvertebrate communities of the Niobrara River, Agate Fossil Beds National Monument of America, Nebraska and chosen as indicative of changing water quality through time. An asterisk indicates metrics originally selected by Peterson (1996).

Metric (Reference)	Definition	Expected Response
Density* (Plafkin et al. 1989)	Number of all individuals present per sample. Reported as individuals per m^2	Lower macroinvertebrate densities indicate that a stream may have been subjected to one or more stresses.
Family Biotic Index* (Hilsenhoff 1988)	$FBI = \Sigma n_i a_i / N$ N is the total number of individuals in a sample, n_i is the total number of individuals in a family, and a_I the tolerance value for the *i*th family.	Higher FBI indicates that a stream may have been subjected to one or more stresses. This index weights the relative abundance of each family by its relative pollution tolerance value to determining a community score. Therefore, pollution-tolerant species are weighted heavier than pollution-sensitive species in the index.
Genus Diversity* (Shannon-Wiener 1949)	$H' = -\Sigma(n_i / N)*\ln(n_i / N)$ N is the total number of individuals in a sample and n_i is the total number of individuals in the *i*th genus.	Lower diversity indicates that a stream may have been subjected to one or more stresses.
Genus Richness* (Resh and Grodhaus 1983)	Number of genus present per sample.	Lower richness indicates that a stream may have been subjected to one or more stresses.
Genus Evenness (Pielou 1966)	A measure of how evenly the total number of individuals are distributed across the genus's. J' = H′/ln(genus richness)	Lower evenness indicates that a stream may have been subjected to one or more stresses and is being populated disproportionately by a few genus's, usually pollution tolerant genus's.
EPT Richness (Resh and Grodhaus 1983)	Number of Ephemeroptera, Plecoptera, and Trichoptera taxa present per sample.	Lower richness indicates that a stream may have been subjected to one or more pollution stresses. In general, the majority of taxa in these three orders are pollution sensitive.

Statistical Analysis Methods. The macroinvertebrate indices for the Niobrara River were compared graphically using means and an estimate of variance. This analysis approach was chosen over other statistical analysis options given there was an imbalance among years in the number of samples. Specifically, in 1989 and 1996 samples were collected on only one date (Appendix A). During 1997–2002, samples were collected on three different dates within each year, exception being 1998 when samples were collected on only two dates. Also, during 1997 samples were not collected in August from the Agate Middle site. Between 1996 and 1998 and again in 2002 less than five hester-dendy samplers were recovered at some sample sites on certain dates. Spring flooding washed some samplers down stream and late season droughts have resulted in samplers resting in the mud on the bottom. Some samplers may have also been affected by debris washing against them during deployment.

Annual means and standard errors were calculated from means for each sample site and date. These means and standard errors, were graphed and used to make annual water quality comparisons for the Niobrara River within the monument. As more data is collected, annual variations in the water quality of the Niobrara River will be investigated using more rigorous statistical methods. The U.S. Geological Survey has agreed to undertake a project to design a statistical analysis of trends in water quality of the Niobrara River based on collected data. Both, the correlation of data collected at the same site through time and the lack of independence of samples collected at a site on any given date will be considered in this future design.

RESULTS AND DISCUSSION

The macroinvertebrate indices for the Niobrara River across years are reported in Table 2 and Figure 2. The data are also reported by date and sampling site in Appendix A.

Table 2. Niobrara River, Agate Fossil Beds National Monument, Nebraska macroinvertebrate indices; means and standard errors.

	Mean (SE)							
Macroinvertebrate Index	**1989 n = 1**	**1996 n = 2**	**1997 n = 8**	**1998 n = 6**	**1999 n = 9**	**2000 n = 9**	**2001 n = 9**	**2002 n = 9**
Density	3468.25	1238.97	3700.35	5077.14	3733.29	5501.02	5923.69	2697.17
	(na)	(95.80)	(718.12)	(1270.85)	(718.73)	(1447.74)	(755.65)	(207.95)
Family Biotic Index	5.22	4.22	3.51	5.25	3.50	2.92	3.74	4.00
	(na)	(0.18)	(0.26)	(0.47)	(0.20)	(0.14)	(0.25)	(0.23)
Genus Diversity	1.73	1.12	1.32	1.54	1.43	1.06	1.57	1.55
	(na)	(0.21)	(0.09)	(0.20)	(0.13)	(0.09)	(0.09)	(0.07)
Genus Richness	15.60	9.90	14.54	12.16	16.76	9.07	12.33	10.51
	(na)	(0.30)	(1.52)	(1.85)	(1.95)	(0.46)	(0.74)	(0.58)
Genus Evenness	0.63	0.48	0.52	0.64	0.52	0.49	0.63	0.67
	(na)	(0.08)	(0.05)	(0.03)	(0.04)	(0.05)	(0.03)	(0.02)
EPT Richness	5.00	4.80	5.75	3.23	6.31	5.53	5.67	5.20
	(na)	(0.20)	(0.67)	(0.55)	(0.31)	(0.39)	(0.24)	(0.21)

Year 1989 is represented by only five replicates collected at Agate Spring Ranch on 12 July 1989 (Appendix A). Therefore, 1989 data will not serve as baseline data for change comparisons with other years. 1989 data serves only to represent water conditions at Agate Spring Ranch on the date listed.

Density (Fig. 2a), the number of individuals present per sample, reported as individuals per m^2 has increased each year since 1996, with the exception of 1999 and 2002. Based on means and overlapping standard errors, 1999 average densities were lower, but not significantly from other years. However, average density was significantly lower in 2002, than in other years since 1996. Increasing density appears to be a relatively uniform event across species groups. Genus Evenness (Fig. 2e), a measure of how evenly individuals are distributed across species groups, has shown improved values with time. Again, Genus Evenness values in later years are significantly better than earlier years.

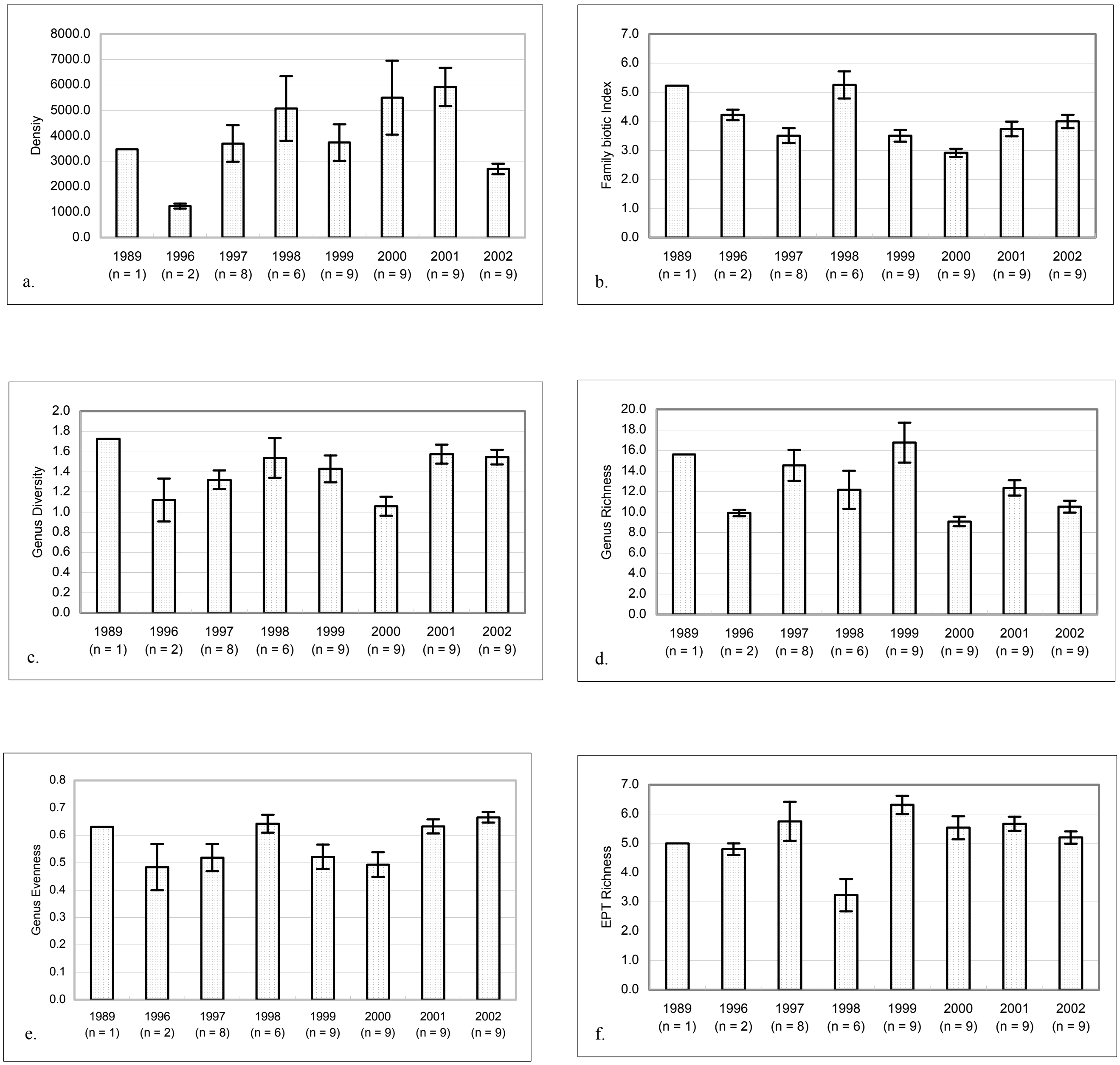
The Family Biotic Index values (Fig. 2b) indicates that water quality improved from 1996 to 1997 then declined sharply in 1998. Family Biotic Index values improved again in 1999 and

2000, but show a declining trend in 2001and 2002. EPT Richness values (Fig. 2f) provide a mirror image of Family Biotic Index values. As pollution tolerant Chironomidae declined so did the Family Biotic Index. Simultaneously the number of pollution intolerant species increased, resulting in higher EPT Richness. Therefore, both Family Biotic Index and EPT richness suggest that water quality in the Niobrara River at Agate Fossil Beds National Monument has remained reasonably constant over time, showing a slight decline in quality since 2001.

Genus Diversity (Fig. 2c) and to some extent Genus Richness (Fig. 2d) values suggest that water quality was better during 1998-1999, when compared to earlier years. Genus Diversity also suggest that water quality in the Niobrara River at Agate Fossil Beds National Monument has remained unchanged since 1998, with the exception of year 2000, which declined significantly based on overlapping standard errors. Genus Richness also declined significantly in 2000. However, Genus Richness improved in 2001-2002 to levels observed in earlier years.

In summary, it appears that water in the Niobrara River at Agate Fossil Beds National Monument, while fluctuating, is of good quality and may have improved slightly between 1996 and 2001. However, a slight decline in water quality was noted in 2002. It is important to keep in mind that data from the Niobrara River has not been compared to reference streams in the region, and the observed changes are relative to initial conditions. However, the Niobrara River at Agate Fossil Beds National Monument may very well serve as a high quality reference stream for that region of Nebraska. Both the results of our data and Water Resource Division (1999) having identified only a few instances when water quality has dropped below recognized standards between 1952 and 1993 suggest it is a stream of high quality. An expansion of the water quality monitoring within the Monument to include chemical and physical measures, as well as the biotic measure will help to identify and document any future declines in water quality, if they occur. Both chemical and physical measures serve to help identify potential cause for changes in biotic communities, as well as serve as indicator of changing water conditions themselves. The addition of both chemical and physical measures to our macroinvertebrate monitoring effort will also allow us to more readily compare our data with regionally collected water quality data.

Figure 2. Niobrara River, Agate Fossil Beds National Monument, Nebraska macroinvertebrate index means (standard error) by sample year.



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Appendix A. Means (SE) of macroinvertebrate indices for Niobrara River, Agate Fossil Beds National Monument, Nebraska.

Sample Date	N	Total Taxa Density	Total Taxa Diversity	Total Taxa Richness	Total Taxa Evenness	FBI	Genus Diversity	Genus Richness	Genus Evenness	EPT Richness
					Agate Spring Ranch					
7/12/89	5	3468.25 (468.23)	1.73 (0.10)	15.60 (1.17)	0.63 (0.03)	5.22 (0.11)	1.73 (0.10)	15.60 (1.17)	0.63 (0.03)	5.00 (0.45)
7/17/96	5	1334.77 (197.52)	0.91 (0.14)	9.60 (1.21)	0.40 (0.04)	4.04 (0.04)	0.91 (0.14)	9.60 (1.21)	0.40 (0.04)	5.00 (0.63)
7/31/97*	5	3246.50 (309.57)	1.47 (0.19)	19.20 (2.99)	0.50 (0.04)	3.55 (0.07)	1.47 (0.19)	19.20 (2.99)	0.50 (0.04)	8.40 (0.93)
8/27/97	5	3407.97 (566.35)	1.38 (0.09)	12.80 (1.07)	0.55 (0.04)	3.22 (0.14)	1.38 (0.09)	12.80 (1.07)	0.55 (0.04)	5.20 (0.37)
9/24/97	5	2251.88 (372.02)	1.41 (0.13)	14.80 (1.88)	0.53 (0.03)	3.69 (0.13)	1.41 (0.13)	14.80 (1.88)	0.53 (0.03)	7.00 (0.71)
7/2/98	5	4540.37 (711.91)	2.15 (0.09)	18.60 (1.69)	0.74 (0.01	5.02 (0.14)	2.15 (0.09)	18.60 (1.69)	0.74 (0.01)	4.20 (0.49)
9/1/98*	4	3912.81 (1518.29)	0.85 (0.10)	6.00 (1.41)	0.60 (0.15)	3.39 (0.55)	0.85 (0.10)	6.00 (1.41)	0.60 (0.15)	3.50 (0.87)
7/20/99	5	2157.16 (349.49)	1.13 (0.08)	9.20 (1.46)	0.53 (0.02)	3.89 (0.08)	1.13 (0.08)	9.20 (1.46)	0.53 (0.02)	5.80 (0.73)
8/23/99	5	4703.98 (547.16)	1.00 (0.05)	12.20 (1.16)	0.41 (0.03)	2.87 (0.13)	1.00 (0.05)	12.20 (1.16)	0.41 (0.03)	6.40 (0.51)
9/27/99*	5	3496.23 (121.80)	0.94 (0.12)	15.20 (1.24)	0.34 (0.03)	2.72 (0.12)	0.94 (0.12)	15.20 (1.24)	0.34 (0.03)	5.60 (0.68)
7/18/00	5	4111.95 (562.84)	1.26 (0.06)	8.60 (1.44)	0.61 (0.04)	3.25 (0.10)	1.26 (0.06)	8.60 (1.44)	0.61 (0.04)	6.80 (0.58)
8/22/00	5	4757.80 (311.09)	0.87 (0.09)	7.20 (1.20)	0.45 (0.03)	2.72 (0.10)	0.87 (0.09)	7.20 (1.20)	0.45 (0.03)	4.40 (0.51)
9/18/00	5	3427.34 (264.23)	0.76 (0.09)	7.60 (0.75)	0.38 (0.03)	2.61 (0.07)	0.76 (0.09)	7.60 (0.75)	0.38 (0.03)	3.40 (0.24)
7/24/01*	5	6820.24 (835.64)	1.38 (0.18)	11.60 (1.25)	0.56 (0.05)	3.14 (0.27)	1.38 (0.18)	11.60 (1.25)	0.56 (0.05)	6.20 (0.49)
8/21/01	5	5166.85 (758.37)	1.03 (0.09)	7.60 (0.60)	0.51 (0.03)	2.88 (0.17)	1.03 (0.09)	7.60 (0.60)	0.51 (0.03)	4.40 (0.40)
9/25/01	5	4374.60 (860.77)	1.54 (0.05)	10.60 (0.87)	0.66 (0.04)	3.45 (0.14)	1.54 (0.05)	10.60 (0.87)	0.66 (0.04)	4.60 (0.40)
7/11/02	4	3568.35 (684.95)	1.43 (0.21)	9.00 (2.00)	0.66 (0.10)	3.90 (0.22)	1.43 (0.21)	9.00 (2.00)	0.66 (0.10)	5.00 (0.82)
8/20/02	5	2273.41 (933.53)	1.16 (0.16)	7.80 (1.64)	0.57 (0.05)	3.05 (0.20)	1.16 (0.16)	7.80 (1.64)	0.57 (0.05)	4.00 (1.22)
9/16/02	5	2286.33 (594.36)	1.63 (0.14)	12.40 (3.78)	0.66 (0.05)	4.38 (0.48)	1.63 (0.14)	12.40 (3.78)	0.66 (0.05)	5.00 (1.87)
					Agate East					
7/17/96	5	1143.16 (291.48)	1.33 (0.23)	10.20 (1.02)	0.57 (0.08)	4.40 (0.28)	1.33 (0.23)	10.20 (1.02)	0.57 (0.08)	4.60 (0.24)
7/31/97**	5	6785.79 (1793.84)	0.76 (0.10)	14.00 (2.05)	0.30 (0.04)	2.63 (0.16)	0.76 (0.10)	14.00 (2.05)	0.30 (0.04)	6.00 (0.45)
8/27/97	4	4806.24 (1079.70)	1.12 (0.06)	13.00 (1.96)	0.45 (0.04)	3.17 (0.10)	1.12 (0.06)	13.00 (1.96)	0.45 (0.04)	5.50 (0.87)
9/24/97	5	5593.11 (948.49)	1.57 (0.17)	21.20 (2.27)	0.52 (0.06)	3.45 (0.23)	1.57 (0.17)	21.20 (2.27)	0.52 (0.06)	6.40 (0.40)
7/2/98	5	2712.59 (301.09)	1.25 (0.21)	8.60 (1.29)	0.58 (0.09)	4.67 (0.22)	1.25 (0.21)	8.60 (1.29)	0.58 (0.09)	2.80 (0.37)
9/1/98*	5	3677.07 (140.58)	2.01 (0.16)	14.80 (1.24)	0.75 (0.04)	6.18 (0.27)	2.01 (0.16)	14.80 (1.24)	0.75 (0.04)	5.20 (0.92)
7/20/99	5	6385.36 (832.86)	2.13 (0.08)	26.40 (2.89)	0.66 (0.02)	4.12 (0.08)	2.13 (0.08)	26.40 (2.89)	0.66 (0.02)	7.40 (0.51)
8/23/99	5	7642.63 (428.63)	1.30 (0.02)	24.60 (1.08)	0.41 (0.01)	3.20 (0.13)	1.30 (0.02)	24.60 (1.08)	0.41 (0.01)	8.00 (0.89)
9/27/99*	5	3804.09 (925.47)	1.39 (0.26)	20.60 (1.29)	0.46 (0.08)	3.20 (0.36)	1.39 (0.26)	20.60 (1.29)	0.46 (0.08)	6.60 (0.60)
7/18/00	5	7384.28 (732.86)	1.11 (0.12)	10.80 (0.37)	0.47 (0.06)	2.72 (0.11)	1.11 (0.12)	10.80 (0.37)	0.47 (0.06)	7.20 (0.37)

Appendix A. continued.

Sample Date	N	Total Taxa Density	Total Taxa Diversity	Total Taxa Richness	Total Taxa Evenness	FBI	Genus Diversity	Genus Richness	Genus Evenness	EPT Richness
8/22/00	5	15801.94 (2463.98)	0.56 (0.02)	10.20 (1.02)	0.24 (0.01)	2.34 (0.03)	0.56 (0.02)	10.20 (1.02)	0.24 (0.01)	6.20 (0.58)
9/18/00*	5	6897.74 (619.99)	1.03 (0.06)	11.20 (1.07)	0.43 (0.01)	2.76 (0.05)	1.03 (0.06)	11.20 (1.07)	0.43 (0.01)	5.20 (0.37)
7/24/01*	5	4387.51 (1071.47)	1.77 (0.13)	12.80 (1.56)	0.70 (0.03)	3.80 (0.26)	1.77 (0.13)	12.80 (1.56)	0.70 (0.03)	6.20 (0.49)
8/21/01	5	8473.63 (1573.17)	1.46 (0.08)	13.60 (0.93)	0.56 (0.03)	3.12 (0.09)	1.46 (0.08)	13.60 (0.93)	0.56 (0.03)	6.20 (0.20)
9/25/01	5	8942.95 (877.50)	1.62 (0.11)	13.20 (1.20)	0.63 (0.03)	5.28 (0.17)	1.62 (0.11)	13.20 (1.20)	0.63 (0.03)	5.60 (0.40)
7/11/02	5	2389.67 (680.62)	1.77 (0.24)	12.80 (2.68)	0.70 (0.06)	3.93 (0.35)	1.77 (0.24)	12.80 (2.68)	0.70 (0.06)	6.00 (0.71)
8/20/02	5	3836.38 (876.40)	1.30 (0.12)	10.00 (3.16)	0.58 (0.04)	3.01 (0.19)	1.30 (0.12)	10.00 (3.16)	0.58 (0.04)	5.80 (0.84)
9/16/02	5	2443.49 (585.64)	1.50 (0.18)	9.20 (1.30)	0.68 (0.09)	4.58 (0.53)	1.50 (0.18)	9.20 (1.30)	0.68 (0.09)	4.60 (0.55)
					Agate Middle					
7/31/97*	3	3272.34 (526.50)	1.34 (0.17)	14.33 (0.67)	0.50 (0.06)	3.24 (0.24)	1.34 (0.17)	14.33 (0.67)	0.50 (0.06)	5.67 (1.33)
9/24/97*	5	238.97 (81.58)	1.50 (0.16)	7.00 (1.26)	0.80 (0.05)	5.13 (0.57)	1.50 (0.16)	7.00 (1.26)	0.80 (0.05)	1.80 (0.80)
7/2/98*	4	11297.09 (1573.97)	1.48 (0.14)	13.75 (0.85)	0.56 (0.04)	6.50 (0.15)	1.48 (0.14)	13.75 (0.85)	0.56 (0.04)	1.50 (0.50)
9/1/98*	5	4322.93 (947.90)	1.48 (0.19)	11.20 (1.07)	0.62 (0.08)	5.78 (0.63)	1.48 (0.19)	11.20 (1.07)	0.62 (0.08)	2.20 (0.80)
7/20/99*	5	1498.39 (262.42)	1.91 (0.13)	12.60 (1.40)	0.76 (0.02)	4.41 (0.31)	1.91 (0.13)	12.60 (1.40)	0.76 (0.02)	5.40 (0.60)
8/23/99*	5	2150.70 (287.17)	1.53 (0.12)	15.40 (1.03)	0.56 (0.04)	3.19 (0.17)	1.53 (0.12)	15.40 (1.03)	0.56 (0.04)	6.40 (0.24)
9/27/99**	5	1761.03 (443.15)	1.52 (0.10)	14.60 (0.75)	0.57 (0.04)	3.90 (0.31)	1.52 (0.10)	14.60 (0.75)	0.57 (0.04)	5.20 (0.20)
7/18/00*	5	1451.02 (519.43)	1.44 (0.19)	8.60 (1.63)	0.68 (0.05)	3.76 (0.03)	1.44 (0.19)	8.60 (1.63)	0.68 (0.05)	5.80 (1.16)
8/22/00*	5	3823.47 (700.54)	1.21 (0.04)	8.60 (1.17)	0.58 (0.03)	2.92 (0.08)	1.21 (0.04)	8.60 (1.17)	0.58 (0.03)	5.80 (0.86)
9/18/00*	5	1853.61 (436.72)	1.27 (0.15)	8.80 (0.92)	0.59 (0.07)	3.18 (0.24)	1.27 (0.15)	8.80 (0.92)	0.59 (0.07)	5.00 (0.84)
7/24/01*	5	3349.84 (730.98)	2.05 (0.09)	15.40 (0.24)	0.75 (0.03)	4.18 (0.25)	2.05 (0.09)	15.40 (0.24)	0.75 (0.03)	6.20 (0.66)
8/21/01*	5	3375.67 (958.62)	1.68 (0.05)	12.60 (1.75)	0.68 (0.03)	3.51 (0.07)	1.68 (0.05)	12.60 (1.75)	0.68 (0.03)	6.20 (0.86)
9/25/01	5	8421.96 (1379.61)	1.65 (0.06)	13.60 (1.03)	0.64 (0.03)	4.30 (0.17)	1.65 (0.06)	13.60 (1.03)	0.64 (0.03)	5.40 (0.24)
7/11/02	5	3005.38 (1757.02)	1.74 (0.15)	10.80 (1.79)	0.74 (0.05)	4.85 (0.39)	1.74 (0.15)	10.80 (1.79)	0.74 (0.05)	5.60 (0.55)
8/20/02	5	2355.22 (647.04)	1.58 (0.13)	10.20 (2.68)	0.69 (0.05)	3.52 (0.14)	1.58 (0.13)	10.20 (2.68)	0.69 (0.05)	5.40 (0.89)
9/16/02	5	2116.25 (961.36)	1.79 (0.15)	12.40 (1.14)	0.71 (0.04)	4.73 (0.56)	1.79 (0.15)	12.40 (1.14)	0.71 (0.04)	5.40 (0.89)

* An event occurred during deployment that could potentially influence the results on this sample date (e.g. flood during sampler deployment).
** Two or more events occurred during deployment that could potentially influence the results on this sample date (e.g. flood during sampler deployment).